

What is Claimed is:

1 1. A method for forming an integrated multiple
2 optical element comprising:
3 providing a bonding material surrounding each
4 first optical element in an array of first optical
5 elements on a first wafer;
6 aligning a second wafer containing an array of
7 second optical elements with said first wafer;
8 treating the bonding material to thereby bond the
9 aligned wafers; and
10 dicing the bonded wafers, each diced, bonded wafer
11 containing at least one optical element for each of the
12 first and second wafers, thereby forming an integrated
13 multiple optical element.

1 2. The method as recited in claim 1, wherein said
2 aligning step includes aligning fiducial features on
3 each of the substrates to one another.

1 3. The method as recited in claim 1, further
2 comprising, prior to said bonding, lithographically
3 manufacturing the optical elements.

1 4. The method as recited in claim 1, further
2 comprising, prior to said bonding, replicating the
3 optical elements using a master to emboss the optical
4 elements into a polymer on a wafer.

1 5. The method as recited in claim 1, further
2 comprising, prior to said aligning, precisely providing
3 stand offs on said first wafer in order to ensure an
4 appropriate gap between said first and second wafers.

1 6. The method as recited in claim 1, wherein the
2 bonding material is UV cured epoxy and said bonding
3 includes curing said epoxy.

1 7. The method as recited in claim 1, wherein the
2 bonding material is solder and said bonding includes
3 reflowing and hardening the solder.

1 8. The method according to claim 1, wherein the
2 adhesive provides sufficient sealing that a dicing
3 slurry applied during said dicing is prevented from
4 entering the gap between the substrates.

1 9. The method as recited in claim 1, further
2 comprising providing metalized pads on a surface
3 opposite said bonding surface for assisting and bonding
4 an aligning the multiple optical element with active
5 elements.

1 10. The method as recited in claim 1, further
2 comprising providing stand-offs on said first wafer,
3 said stand-offs surrounding each first optical element.

1 11. The method as recited in claim 10, further
2 comprising providing solder on top of said stand-offs.

1 12. The method as recited in claim 10, further
2 comprising providing a liquid adhesive in a channel
3 formed by said stand-offs.

1 13. The method as recited in claim 1, further
2 comprising providing alignment areas on each integrated
3 element for bonding with active elements.

1 14. The method as recited in claim 1, further
2 comprising providing fiducial marks on said first and
3 second wafers.

1 15. A method of making optical elements on a
2 wafer level comprising:

3 lithographically making a master including an
4 array of optical elements;

5 embossing a replica of said array of optical
6 elements by applying said master to an embossable
7 material; and

8 dicing said replica to form individual optical
9 elements.

1 16. The method as recited in claim 15, further
2 comprising providing said embossable material in a thin
3 film on a surface of the master prior to the embossing.

1 17. The method as recited in claim 16, further
2 comprising providing an adhesion promoter on a glass
3 substrate prior to the embossing.

1 18. The method as recited in claim 16, wherein
2 said glass substrate contains fiducial marks and
3 further comprising aligning said master to the fiducial
4 marks.

1 19. The method as recited in claim 15, further
2 comprising coating said replica with an anti-reflective
3 coating.

1 20. The method according to claim 15, further
2 comprising selectively removing material from or adding
3 material to said replica in a predetermined pattern.

1 21. The method according to claim 20, wherein
2 said selectively removing or adding occurs prior to
3 said embossing.

1 22. The method according to claim 20, wherein
2 said selectively removing or adding occurs after said
3 embossing.

1 23. The method according to claim 20, wherein
2 said selectively removing or adding includes providing

3 metal pads on a surface opposite a side of said replica
4 subject to said embossing.

1 24. The method according to claim 15, wherein
2 said embossing includes embossing both sides of said
3 glass substrate.

1 25. The method according to claim 24, wherein a
2 different wafer master is used for embossing either
3 side of said both sides.

1 26. The method according to claim 25, wherein a
2 first wafer master includes diffractive optical
3 elements and a second wafer master includes refractive
4 optical elements.

1 27. The method according to claim 15, further
2 comprising providing fiducial marks on both said wafer
3 master and said replica.

1 28. The method according to claim 15, further
2 comprising confirming alignment of said replica and
3 said wafer master in a mask aligner and tacking
4 together said replica and wafer master once alignment
5 is confirmed.

1 29. The method according to claim 28, further
2 comprising removing said replica and said wafer master

3 from the mask aligner after said tacking and curing the
4 embossable material.

1 30. The method according to claim 15, wherein
2 said applying includes initially bringing said wafer
3 master into incomplete contact with said replica.

1 31. An integrated dual sided multiple optical
2 element comprising:

3 a substrate having two surfaces;

4 lithographically defined optics on both surfaces;

5 and

6 additional lithographically defined features on at
7 least one surface from which material is selectively
8 removed or added at one time.

1 32. The optical element according to claim 31,
2 wherein one surface of said substrate includes a
3 diffractive element for providing at least one of beam
4 splitting, creating multiple spots and diffusely
5 illuminating a specific area.

1 33. The optical element according to claim 32,
2 wherein said diffractive element is a plurality of
3 diffractive elements.

1 34. The optical element according to claim 31,
2 wherein said substrate is a wafer and said optics are
3 an array of optical elements.

1 35. The optical element according to claim 31,
2 wherein said additional lithographically defined
3 features include metal portions for blocking light.

1 36. The optical element according to claim 31,
2 wherein said additional lithographically defined
3 features include metal portions for assisting in
4 bonding active element to the integrated multiple
5 optical element.

1 37. An optical element formed by the process
2 recited in claim 1.

1 38. An optical element formed by the process
2 recited in claim 15.

1 39. A hybrid optical element comprising a
2 refractive optical element and a diffractive pattern
3 formed on a curved surface of said refractive optical
4 element.

1 40. The optical element as recited in claim 39,
2 wherein said refractive optical element is formed
3 lithographically.

1 41. The method as recited in claim 15, wherein
2 said master is a wafer.

1 42. The method as recited in claim 20, wherein
2 said selectively removing or adding is lithographic.

1 43. The method as recited in claim 20, wherein
2 said selectively removing or adding includes
3 selectively removing embossable material.

1 44. The method as recited in claim 43, wherein
2 said selectively removing embossable material includes
3 providing metal in a pattern on said master and, after
4 said embossing, washing away uncured embossable
5 material.

1 45. The method as recited in claim 43, wherein
2 said selectively removing or adding includes adding
3 material where embossable material was removed.

1 46. The method as recited in claim 28, wherein
2 said tacking includes providing localized curing of
3 said embossable material.

1 47. The optical element as recited in claim 31,
2 wherein optics on one surface are refractive and optics
3 on another surface are diffractive.

1 48. The optical element as recited in claim 31,
2 wherein optics on at least one of said two surfaces are
3 formed by embossing.

1 49. The optical element as recited in claim 31,
2 wherein lithographically defined optics include forming
3 a master photolithographically and embossing optics
4 using said master.

1 50. The optical element as recited in claim 31,
2 further comprising features embossed from a
3 photolithographically created master.